ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 6 (2011) 750–758

Energy Procedia

MEDGREEN 2011-LB

Hybrid Options Analysis for Power Systems for Rural Electrification in Algeria

D.Saheb-Koussa [a], M.Koussa [a] M.Haddadi [b], & M.Belhamel[a]

[a]*First affiliation, Address, City and Postcode, Country***Centre de Développment des Energies Renouvelable Route de l'observatoire, BP.62 Bouzareah, Alger, Algérie*

[b] *Laboratoire de Dispositif de Communication et de Conversion Photovoltaïque E. N. P, 10 Avenue Hassen Badi, El Harrach, Alger, Algérie*

Abstract

Adrar **,** Djelfa, Illizi and Djanet , are the most rural zones in Algeria where grid connected electric system for the inhabitants will not be possible to establish even in future. Diesel is the main fuel for fulfilling the energy demand. Solar and Wind resources are the hybrid options for these four sites. HOMER, a software for optimization of renewable based energy efficient system for different numbers of households- 1, 20. It shows that per unit (kWh) cost of energy varies from 1.49, 2.46, 1.84 and 4.1 USD to 1.19, 2.16, 1.33, and 1.52 USD respectively for **:** Adrar **,** Djelfa , Illizi and Djanet. . On the other hand it's revealed too that the energy cost depends largely on the renewable energy potential quality (Adrar : 1.19 USD and Djelfa 2.16 USD).

Hybrid options, power systems, rural electrification.;

1. INTRODUCTION

In remote Algerian's villages, far from the grids, electric energy is usually supplied by diesel generators. In most of this cases, the supply with diesel fuel becomes highly expensive while hybrid/photovoltaic/wind generation becomes competitive with diesel only generation [1], [2] . Photovoltaic/wind/diesel hybrid systems are more reliable in producing electricity than photovoltaic only/wind only systems, and often present the best solution for electrifying remote areas. The diesel generator reduces the photovoltaic/wind component while the photovoltaic/wind systems decrease the operating time of the generator, reducing the running costs of the diesel generator [3], the addition of storage reduces the start/ stop cycles of diesel generators thus, considerably reduce the fuel consumption [4] and [5].

In order to effectively explain the benefits of Hybrid system. A program called HOMER [6] was used in this study. HOMER is sophisticated software developed by the National Renewable Energy Laboratory for analyzing the economics of small power systems. After inputting the solar/wind resources along with the cost of equipment HOMER crunches the numbers to give us the "Optimal System Type" based purely on economics and availability of resources.

doi:10.1016/j.egypro.2011.05.085

Analysis has been done for single home user as well as combination of 20 home users to get the most economic and technical viable options. For the purpose of illustration, four Algerian's rural sites have been considered (Adrar, Djelfa, Illizi and Djanet).
Many power hybrid systems have been proposed in the past for remote area but the vast majority had been based on the technical PV- diesel systems or PV-Wind systems [7-19]. Many tools are also available for sizing and simulation of a power hybrid system but fewer included the technical and economic study of the PV-Wind-Diesel hybrid system with battery storage using different load combination and different sites. The authors have adopted a new approach to the PV-Wind-Diesel hybrid system with battery storage including the technical and economic study using different load combination and different sites from a rural Algerian's area.

2. USED DATA

In the present study four Algerian sites have been selected in were solar radiation, ambient temperature and wind speed were available. Thus, the geographical coordinates and the climate type classification according to Koppen Geiger[20] were given also in Table 1.

Table 1. The geographical coordinates and the climate type classification

Site	Latitude (°)	Longitude (°)	Altitude (m)	Climate type
Adrar	27.8 North	0.18 West	264	Bwh[20]
Djelfa	34.4 North	3.15 East	1144	Bwk[20]
Illizi	26.3 North	8.25 East	558	Bwh[20]
Djanet	24.3 North	9.28 East	1054	Bwh[20]

3. PRESENTATION OF THE CASE STUDY

An hybrid energy system generally consists of a primary energy sources working in parallel with the operation of a system by creating energy balance calculations for each of the 8, standby secondary energy storage units. HOMER has been used to optimize the best energy efficient system for Adrar , Djelfa, Illizi and Djanet considering different load and wind-PV-Diesel combination and based on the solar/wind resources . Fig.1 illustrates the schematic of: (a) hybrid energy system for power generation and (b) shows the diagram as realized in HOMER software. HOMER simulates 8,760 hours in a year. After simulating all of the possible system configurations, HOMER presents a list of feasible systems, classified by lifecycle cost.

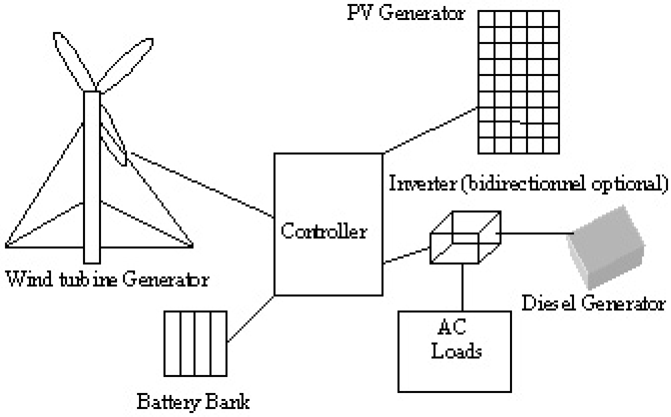


Fig. 1 :(a) Schematic diagram of hybrid energy system

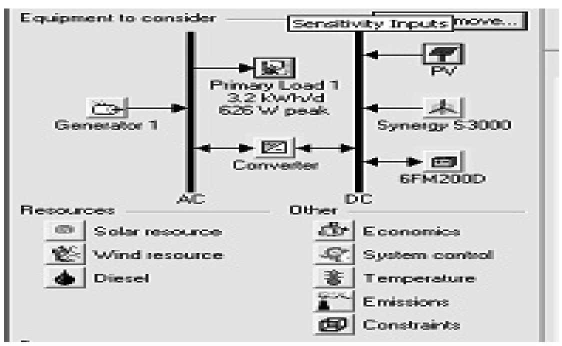


Fig. 1 :(b) Proposed hybrid system in HOMER

Table 2. Appliances for single home user

		Power (W)	*Duration of consumption (hours)*	**Day load (wh)**
Lighting	Rooms	22	8	176
	Lounge	22	6	132
	Corridor	22	3	66
	Bathroom	22	3	66
	Toilet	11	1	11
Equipment	Kitchen	11	7	77
	Refrigerator	120	12	1440
	TV	75	7	525
	FAN	100	4	400
	Various	100	2	200
Total load				3093

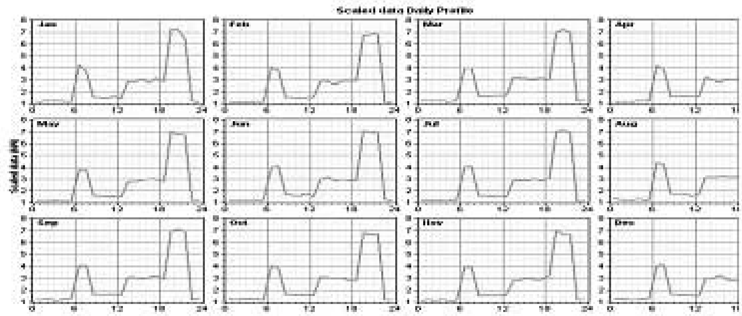


Fig.2: Monthly averaged hourly load profile for 20 home-users

HOMER executes these energy balance calculations for each considered system configuration. It then finds the feasible configuration. Information about the input parameters required for the HOMER software are specified below:

- **Electric load**: A typical load *system* for four sites in a *remote area* in Algeria with *a* typical single residential load (Table 1) has been considered for the present case of analysis. As software (HOMER) input, monthly average hourly load demand has been take into account and then it produces daily and monthly load profile for 20 homes.(Fig. 2). It has been found that for this system each home user consume energy around 3200 Wh/day with a peak demand of nearly 626 W.
- **Renewable resources**: The hourly data global radiation data has been taken from (WMO/OMM) [21] HOMER introduces clearness index from the latitude information of the selected site (Fig. 3) :(a) Hourly global radiation Data and (b)Hourly ambient temperature Data.

For wind Hourly measured data has been used with the information of height = 10m (WMO/ OMM) [21].HOMER generated and synthesized the monthly average data based on the other parameters such as:

- Illizi

Weibull factor ”k”= 1.61 , Autocorrelation factor= 0.905, Diurnal pattern strength(wind speed variation over a day)=0.313 , Hour of peak wind speed = 16 to generate hourly data for a year.

- Adrar

Weibull factor ”k”= 2.35 , Autocorrelation factor= 0.961, Diurnal pattern strength(wind speed variation over a day)=0.153 , Hour of peak wind speed = 16 to generate hourly data for a year.

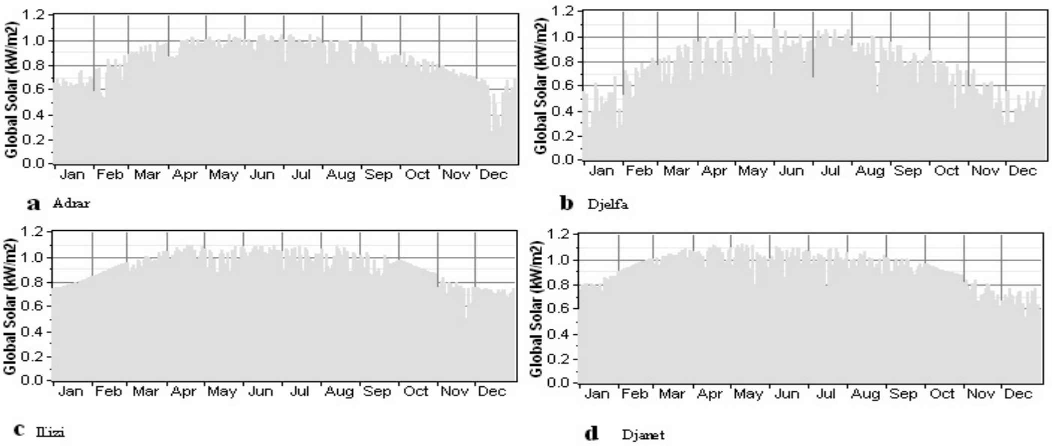
- Djelfa

Weibull factor ”k”= 1.83 , Autocorrelation factor= 0.929, Diurnal pattern strength(wind speed variation over a day)=0.182 , Hour of peak wind speed = 16 to generate hourly data for a year.

- Djanet

Weibull factor ”k”= 1.52 , Autocorrelation factor= 0.931, Diurnal pattern strength(wind speed variation over a day)=0.286 , Hour of peak wind speed = 16 to generate hourly data for a year.

Figure 4 shows (a) the wind speed probability distribution function and (b) averaged hourly wind speed for 1year.



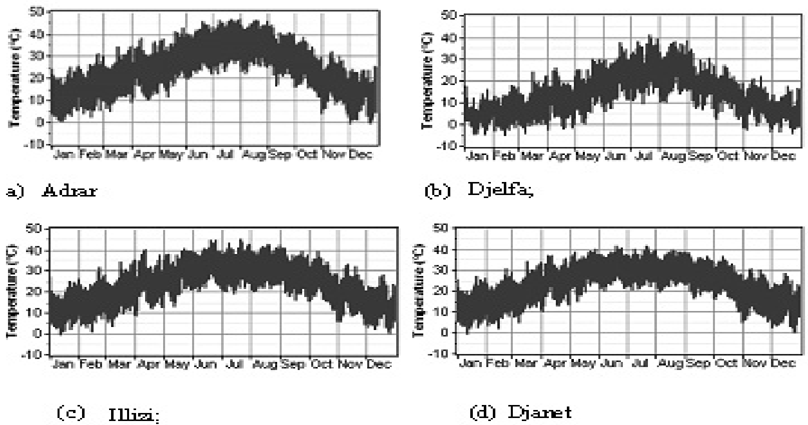
a Adrar

b Djelfa

c Ilizi

d Djanet

Fig 3 :(a) Hourly global radiation Data



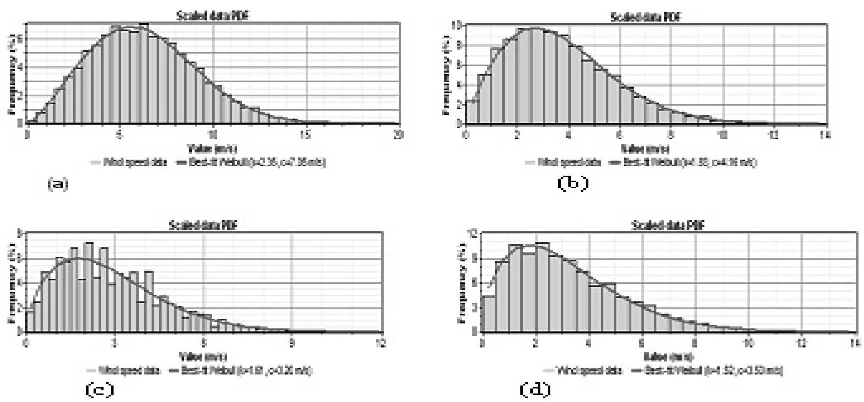
a) Adrar

(b) Djelfa;

(c) Illizi;

(d) Djanet

Fig.3 : (b) Hourly ambient temperature Data



(a)

(b)

(c)

(d)

Fig. 4: (a) Wind speed probability density function

(a)Adrar ;(b) Djelfa; (c) Illizi; (d) Djanet

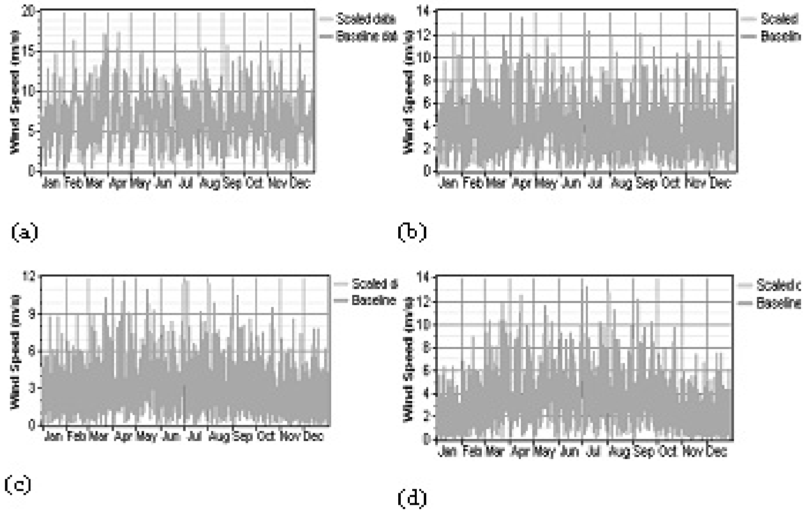


Fig. 4: (b)Daily wind speed for:
(a) Adrar ;(b) Djelfa; (c) Illizi; (d) Djanet

4. HYBRID SYSTEM COMPONENTS

- **Photovoltaic module**: The cost of PV module including installation has been considered as 4 USD/W for Algeria (1USD=72 DZD, 2009[22]). Life time of the modules has been taken as 25 years and these are titled **like the latitude** with no tracking mode.

- **Wind generator:** The load demand is very low for single home system and the price per kW turbine cost is very high for low capacities wind turbine compare to that of high capacity ones. Also low capacity wind turbine is not much available. Now a day, research and development are going on to improve the technology and designing low capacity turbine with low cut- in speed around 2.5 m/s . On the other hand this same wind turbine is used for the site which present the low wind potential, as Djelfa, in the two case : single home and 20 homes system.
So, for these analyses a synergy S 3000 turbine with a capacity of 0.5 kW has been considered. The cost of the turbine with tower and installation has been considered as 6903USD/turbine. For the load higher than 1kW and for the sites which present a high wind potential, turbine from southwest wind power (model Whisper 175; capacity 3kW) has been considered at the cost of 10910 USD with tower and installation.

- **Diesel generator:** Diesel generator supplies a significant amount of energy of 1 and 20 houses. The selected diesel generators have operating hour of 15000, minimum load ratio 30%, 0.2 kW to 5 kW of power is generated by consuming 0.25L/hr of fuel.

- **Battery with controller:** As the system considered the AC load only, battery and controller were also as a main part of the system. Battery from vision battery company (Model Vision 6FM200D; nominal voltage: 12V; nominal capacity: 200Ah) has been used at cost of 853 $ Battery with controller charge.
- **Economics and constraints**: the project life time has been considered to be 25 years and the annual interest rate has been taken 10%. As the system has designed for single and also for 20 house users

but the load consumed by the user is low so operation and maintenance cost has been take 300$ /an. There is no capacity shortage for the system and operating reserve is 10% of hourly load.

5. RESULTS AND DISCUSSION

In this section we present results obtained using the HOMER Software for four rural Algerian sites and for system designed for single and also for 20 house users. Analysis shows that the cost of energy (kWh) is low for the system which is the combination of 20 homes. On the other hand it's revealed too that the energy cost depends largely on the renewable energy potential quality. Table 4 shows the load demand for each combination of homes and each site with system architecture and financial summary. A detailed analysis and system architecture for the 20 homes system and for each site has been given Fig. 5, Fig 6, Fig 7, Fig. 8 respectively for :Adrar, Djelfa, Illizi and Djanet.

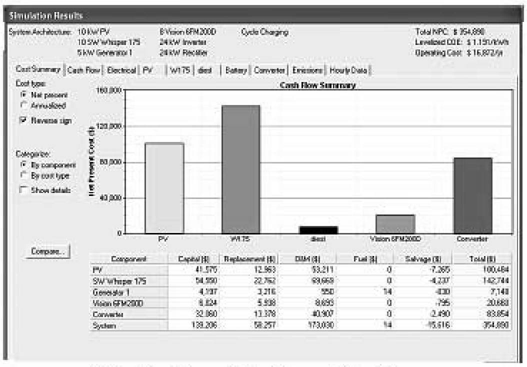


Fig.5 : Simulation results for 20 houses. Site : Adrar

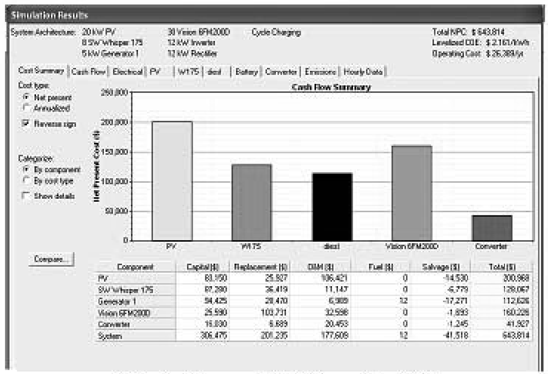


Fig.6 : simulation results for 20 houses. Site : Djelfa

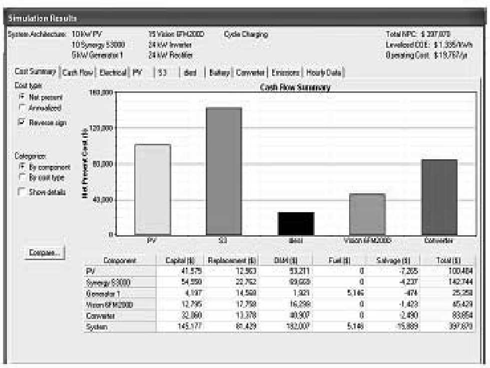


Fig.7 : simulation results for 20 houses. Site : Illizi

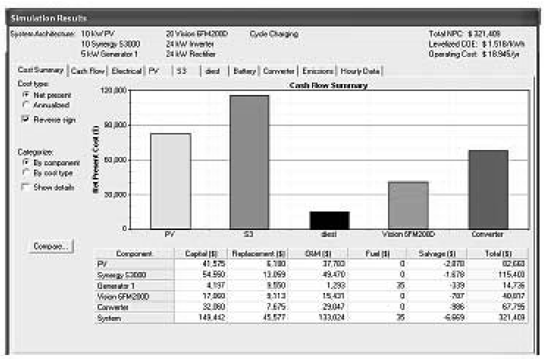


Fig.8 : Simulation results for 20 houses. Site : Djanet

Table 3: HOMER analysis and results

Site	PV module (kW)	Wind Generator (Quantity)	Diesel Generator (kW)	Battery (Quatity)	Initial cost ($)	Total NPC ($)	COE ($/kWh)	Home	Load
Adrar	0.1	1	1	1	8.5	22.3	1.49	single	32.5 Wh/day 6.28 W peak
	10	10	5	8	139.2	354.9	1.19	20	64 kWh/day 1.2 kW peak
Djelfa	0.3	1	1	4	15.18	35.6	2.46	single	32.5 Wh/day 6.28 W peak
	20	8	5	30	306.5	643	2.16	20	64 kWh/day 1.2 kW peak
Illizi	0.5	1	1	1	10.158	27.44	1.84	single	32.5 Wh/day 6.28 W peak
	10	10	5	15	148.8	397.9	1.33	20	64 kWh/day 1.2 kW peak
Djanet	1	3	1	3	24.2	52.8	4.1	single	32.5 Wh/day 6.28 W peak
	10	10	4	20	149	321	1.52	20	64 kWh/day 1.2 kW peak

6. CONCLUSION

This paper was devoted to simulating and sizing a Photovoltaic/Wind/ diesel hybrid system with battery storage for rural electrification in four Algerian's sites. From the results of the system it's designed that, it's recommended to implement similar systems in similar sites . Different combinations of component sizes and quantities has been compared and explored how variations in resource availability and system costs affect the cost of installing and operating different system design. on the other hand, it could be summarized from analysis that it will be better to use pv-wind combination for 20 homes instead of single home system where the per unit (kWh) cost of energy varies from 1.49, 2.46, 1.84 and 4.1 USD to 1.19, 2.16, 1.33, and 1.52 USD respectively for: Adrar **,** Djelfa , Illizi and Djanet which agree with the result obtained by Shamim Kaiser M and al [23]. Thus, the obtained results could be enough to take decision concerning an electrification of remote area in a developing country. This is tool to evaluate and validate the great renewable energy potential available in Algeria.
Finally, the overall system would be low if the turbine and battery cost decreases.

REFERENCES

[1] Colle S., Abreu SL and Ruther R, Economic evaluation and optimisation of hybrid diesel/photovoltaic systems integrated to electricity grid, Sol. Energy (2004); 76**;** 295–9.
[2] Saheb-Koussa D, Haddadi M and Belhamel M. , Economic and Technical Study of Hybrid System for Rural Electrification in Algeria. App. Energy (2009); 86 (7-8); 1024-1030.
[3] Muselli M, Norton G and Louche A, Design of hybrid photovoltaic power generator, with optimisation of energy management, Sol. Energy (1999) **;** 65 (3); 143–57.
[4] Elhadidy MA and Shaahid, SM, Optimal sizing of battery storage for hybrid (wind & diesel) power systems, Renew. Energ*y* (1999); 18**;** 77–86
[5] Elhadidy MA, Performance evaluation of hybrid (wind/solar/diesel) power systems, Renew. Energy (2002); 18; 401–13
[6] HOMER V-2 68 Beta , National Renewable Energy Laboratory (NERL), USA, http://nrel.gov/homer
[7] Bala BK and Siddique SA. Optimal design of a PV-diesel hybrid system for electrification of an isolated island-Sandwip in Bangladesh using genetic algorithm, Energy for sustainable Development 2009;13(3); 137-142.
[8] Ashari M and Nayar CV. An optimum dispatch strategy using set points of a photovoltaic PV-diesel-Battery hybrid power system, Sol. Energy, 1999; 66(1); 1-9.

[9] Phuangpompitak N and Kumar S. PV hybrid systems for rural electrification in Thailand, Renew. and Sustainable Energy Reviews, 2007; 11(7) ;1530- 1543.
[10] Borowy BS and Salameh ZM. Optimum photovoltaic array size for hybrid wind –PV system. IEEE Trans Energy conversion 1994;9(3);482-8.
[11] Borowy BS and Salameh ZM. Methodology for optimally sizing the combination of battery bank and PV array in wind –PV hybrid system.IEEE Trans Energy Conversion.1996; 11(2); 367-75.
[12] Markvart T. Sizing of hybrid photovoltaic –wind energy systems. Solar Energy. 1996; 57(4); 277-35.
[13] Bagul AD. Salameh Zm. And Borrowy BS. Sizing of stand alone hybrid wind-PV system using a three event probability density approximation. Sol. Energy. 1996; 56(4); 323-35.
[14] Morgan TR.,Marshall RH. And Brinkworth BJ.ARES- a refined simulation programme for the sizing and optimization of autonomous hybrid energy systems. Sol. energy. 1997; 59(4); 205-15.
[15] Yang HX, Burnett L. and Lu J. Weather data and probability analysis of hybrid photovoltaic –wind power generation systems in Hong Kong. Renew. Energy 2003; 28(11);1813-24.
[16] Ashok S. Optimised model for community-based hybrid energy system. Renew. Energy2007; 32(7); 1155-64.
[17] Zhou W,Lu L and Yang H. A novel optimization sizing model for hybrid solar-wind power generation system. Sol. Energy 2007;81(1);1813-24.
[18] Lund, H. Large scale integration of optimal combinations of PV, wind and wave power into the electricity supply. Renew. Energy. Vol 31(4) ;pp. 503-15; April 2006.
[19] Kenfack, J., "Microhydro-PV-hybrid system: Sizing a small hydro-PV-hybrid system for rural electrification in developing countries", Renew. Energy, 2009, 10
[20] Peel, M.C., Finlayson , BL. & Mahon, MC. “Updated world mape of the Koppen_Geiger climate classification , Hydrology earth science, 11, 2007,1633-1644.
[21] WMO/OMM , Meteonorm V 5.1, http://www.meteonorm.com
[22] Convertisseur universel de devises de xe.com, http://www.xe.com/fr/
[23] Shamim Kaiser M, Fazlul Haque A.K.M, Arifur Rahman M, Mostafizur Rahman M and Zafor Alam A.M, Hybrid Options Analysis for Power Systems in St. Martin’s Island, Journal of engineering and Appl. Sciences, 2006, 1 (3); 257-261.